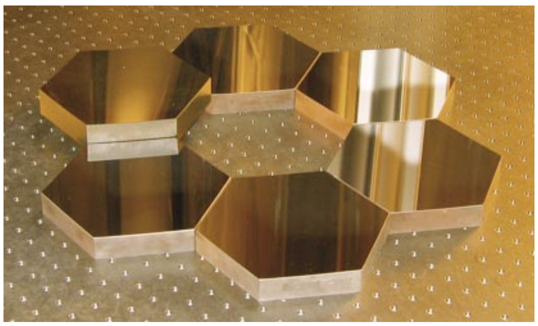
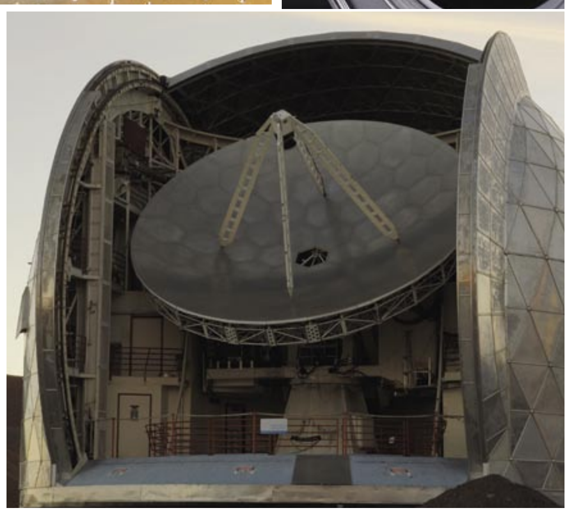
National Aeronautics and Space Administration

optics and photonics

Hybrid Diversity Algorithm for Image-based Wavefront Sensing

... replacing interferometry hardware with a software solution



NASA Goddard Space Flight Center invites companies to license a simple and inexpensive wavefront sensing technology for detecting optical system and reflective surface imperfections. The Hybrid Diversity Algorithm (HDA) can replace an interferometer using software that runs on a standard laptop. The input to the software is “image-based” in the sense that data is collected by a charge coupled device (CCD) or video camera. The software utilizes a novel adaptive iterative process to estimate imperfections in an optical system. This simple innovation provides increased sensing and diagnostic capabilities and allows the use of “broadband” (unfiltered) data. While the technology requires very little additional hardware, which makes it very cost effective, it also provides a highly accurate and precise means for measuring and controlling optical system performance.

Benefits

HDA replaces hardware with a software solution for significant cost savings and a reduction in system complexity, including a reduced risk of system failure. Additional benefits include:

Simplicity:

- Eliminates the need for specialized analog hardware and a wavefront reference, resulting in an easier and faster hardware setup

Increased capability:

- Obtains results using narrowband, monochromatic as well as broadband data
- Is less susceptible to environmental disturbances
- Provides a full range of aberration measurements

Accuracy:

- Can achieve <5 nm accuracy versus >30 nm for other conventional analog processes

Affordability:

- Requires less capital to establish initial hardware and facilities
- Minimizes the need for multiple optical filters by using broadband data

technology opportunity

Applications

- **Optics**: Aspheric optics and surface testing, lens testing, mirror testing, optical system control, characterization of thermal and opto-mechanical disturbances
- **Lasers**: Manufacturing and measurements during operation
- **Semiconductors**: Silicon wafer quality assessment and lithography in the semiconductor
- **Ophthalmic**: Precision lens making, wavefront characterization, and eye surgery
- **Metrology**: Measurement of ultrasmooth surfaces (e.g., DVDs, hard drives)
- **Astronomy**: Optical system control and characterization, measurement of atmospheric turbulence, characterization of thermal and opto-mechanical disturbances
- **Image enhancement**: Corrects surveillance and targeting imagery obtained by satellite or by weaponry (e.g., military); corrects image quality for post-production images (e.g., commercial)

Technology Details

Every optical system suffers to some degree from aberrations or imperfections (e.g., defocus, astigmatism, etc.), whether it's the human eye, telescopes, commercial camera systems, or other systems. Typically, these optical or surface imperfections are detected using interferometry, the conventional established hardware technology. But conventional interferometry has several disadvantages: the hardware can be complex, have significant power requirements, and can be expensive to maintain, calibrate, and configure. These systems also require an external wavefront reference.

How it works

Image–based "phase retrieval" is a general term used in optics to denote the estimation of optical imperfections or aberrations of an optical system, using focal plane data. The particular phase-retrieval sensing technology presented here enables high-spatial-frequency, high-dynamic-range wavefront sensing by incorporating feedback during phase recovery to guide the phase-retrieval process.

The innovation also enables the use of broadband light via supporting technology GSC-14899-1. Since low-order aberration content of the point-spread function of an optical system is not strongly affected by wavelength over the visible spectrum, variations in wavelength do not significantly affect what a phase-retrieval algorithm "sees" as input. As a result of more light being transmitted by broadband than by narrowband filters, detector integration times can be significantly reduced and, therefore, the time needed to perform wavefront sensing can be reduced. In some applications, filters can be eliminated entirely, thereby minimizing the complexity and cost of equipment for testing optical systems.

Via supporting technology (GSC-14900-1), this algorithm can also utilize a filter function that optimally weights wavefront estimates obtained at multiple points distributed over the field of view, providing a more balanced optical performance than a wavefront estimate from a single point in the field of view.

Why it is better

The HDA iterative-transform phase-retrieval algorithm offers both extended dynamic range and the capability to recover high-spatial-frequency components in the wavefronts. While other image-based methods have been developed (e.g., iterative transform and parametric), each has limitations. Earlier iterative-transform-based approaches offer the ability to recover low, middle, and high spatial frequencies, but have a limited dynamic range (one wavelength or less). By contrast, parametric phase retrieval offers the advantage of high dynamic range but is poorly suited for recovering higher spatial frequency aberrations.

NASA Goddard is seeking patent protection for this technology (GSC-14879-1).

Licensing and Partnering Opportunities

This technology is part of NASA's Innovative Partnerships Program, which seeks to transfer technology into and out of NASA to benefit the space program and U.S. industry. NASA invites companies to consider licensing this wavefront sensing technology (GSC-14879-1) for commercial applications. Please note that GSC-14899-1 and GSC-14900-1 are included as supporting technologies but are not licensable.

For More Information

If you are interested in more information or want to pursue transfer of this technology (GSC-14879-1), please contact:

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